A.D. 1862, *26th December.* N° 3453.

Electric Telegraphs.

LETTERS PATENT to Cromwell Fleetwood Varley, of Fortess Terrace, in the County of Middlesex, Electrician, for the Invention of "Improvements in Electric Telegraphs."

Sealed the 9th June 1863, and dated the 26th December 1862.

PROVISIONAL SPECIFICATION left by the said Cromwell Fleetwood Varley, at the Office of the Commissioners of Patents, with his Petition, on the 26th December 1862.

I, Cromwell Fleetwood Varley, of Fortess Terrace, in the County of Middlesex, Electrician, do hereby declare the nature of the said Invention for "Improvements in Electric Telegraphs," to be as follows:—

The object of the said Invention is to obtain a high speed of transmission through long circuits.

This Invention can be applied to almost all if not to all of the existing telegraphic apparatus, viz[t]. it can be applied to the relay or to the signalling instrument direct where no relay is used as is the case with the needle telegraphs, Thomson's reflecting galvanometer, Dignees' inking writer. For ease of explanation, assume that the system of signalling followed to be that described in my Patent No. 371, 1854, in which the signals are produced by a current of one name (+ or —) and the intervals between the signals by a current of

the opposite name (— or +). When the rate of signalling through a long submarine cable is too rapid the electric impluses arrive at the distant end in irregular waves and do not always pass the zero point, that is, do not always change from + to — in which case the relay cannot record the signals which "run together" or "fall out." The electric impulses can be made to appear at the distant end in much more rapid succession if the change of sign (+ to —) be not necessary, and on the 27th January 1860, I patented (vide pages 11 and 12 printed Specification to Patent No. 206,) relays that would indicate these impulses by mechanical means, while the present Invention effects this purpose much more effectually by electrical means, viz.

First mode, at the receiving end of the cable is attached a series of induction plates (vide my Patent No. 2555, 1856, page 4, and Patent No. 206, 1860, page 9, printed Specification)between the earth and the cable connecting the "odd" plates to the one and the "even" plates to the other. A relay or telegraphic instrument is inserted either between the cable and the induction plates or between the induction plates and the earth. A resistance coil (best if wound on a large iron core) is also inserted between the cable and the earth without which no gain in speed would be experienced. Assume a galvanometer relay to be the one used, on applying a current at the sending end, the electric impulse will gradually show itself at the receiving end splitting part into the induction plates and through the galvanometer part through the resistance coils to the earth. As soon as the current assumes its maximum force, and the induction plates are fully charged, the current through the galvanometer ceases. On reversing the current at the sending end the impulse at the receiving end gradually decreases preparatory to changing its sign, the moment however that its tension begins to decrease, and long before it changes sign, the induction plates by discharging themselves produce a reversal of current in the galvanometer, thus the impulse or change of tension is recorded. Any change of the cable current in the direction of plus towards zero, or minus, or of minus to more minus, moves the galvanometer needle in one direction while any variation of the current from minus towards less minus, zero, or plus, moves the needle of the galvanometer in the opposite direction. Fluid induction plates in consequence of their great capacity may be used sometimes with advantage, but as there is always more or less conduction through them, it is necessary to counteract the effect of it in some cases. This can be done by winding the instrument coils with 2 wires and causing a part of the current from the induction plates to pass round the instrument coils in an opposite direction to the first current, when this is over done or over corrected a relay can be constructed which records only when the increment of tension is increasing in rate.

Second mode, by substituting for the instrument coils an electroscope and connecting its two poles by a resistance coil. The electroscope must have several bars for repulsion instead of one, and these must be made short to get rapidity of action. Any increase of tension causes a difference of tension between the cable and the induction plates, because of the resistance coils and this shows itself on the electrometer. By inserting one of my multipliers rotating rapidly any amount of power may be obtained (vide Fig. 20 in my Patent No. 206, 1860).

Third mode, by means of a large electro-magnet requiring a long time to magnetize a similar effect is obtained thus:—The electro-magnet of large dimensions is wrapped with two wires, one acting as a primary, and connected between the cable and the earth, the other acting as a secondary is attached to the telegraph instrument. On passing a current through the primary a current of short duration is produced on the secondary wire, and thus a variation of power of the cable current produces an action in the secondary wire. This records the impulses only as in mode One.

Fourth mode, the instrument coils are wound with two wires and the cable current is made to circulate in opposite directions through them, the current from the one wire goes to the earth through resistance coils, the other part of the current goes to the earth through the coil of an electro-magnet of large dimensions. When the resistances are so adjusted that no action is produced by a steady current through the two wires of the instrument coils the instrument records only the electric impulses owing to the magnetic opposition to any variation of current round the electro-magnet.

Fifth mode, the currents are made to go round two galvanometers of different dimensions and inertia, but so connected as to move in the same direction. These galvanometers are formed into a relay, thus their two axles are placed end to end in the same line, the one carries a contact piece, the other a fork between which the contact piece vibrates. One arm of the fork is insulated, the other not. When the cable current is varying in one direction the local circuit is closed by the lighter needle moving faster than the heavier one. When the current varies in the other direction the local circuit is opened, hence the impulses are recorded as before whether the currents pass the zero or not inducted plates may be placed at the punction of the galvanometers with advantage, or the large electro-magnet or both between that junction and the earth.

Sixth mode, two electro-magnets are used of different dimensions. The large one may be surrounded with a cylinder of copper or a closed helix to make it more sluggish, or the large electro-magnet and a galvanometer acted

upon by the magnet. These latter relays may probably be of great use with type instruments being more rapid in their action, when the afore-mentioned improvements are applied to a relay which works by change of position of its conducting wire in a conducting fluid with two compartments or otherwise (vide my Patent No. 206, 1860, page 12 of printed Specification) the relay may be kept in position by two opposing currents of air forming air stops or cushions, and thus entirely avoiding "sticking" or the relay stops may be made by letting the relay contact piece strike against a wheel or between two wheels rotating. These wheels may be covered with a porous material moistened with any suitable conducting fluid such as chlorides of zinc or calcium, or the relay lever may bring a wire on to a Baines' chemical printing machine, and thus cause marks only when such wire or style is deflected against the prepared chemical paper. By these means very feeble currents are made to record themselves accurately. These various plans may be combined partially or wholly together according to the requirements of the case.

These improvements almost entirely obviate the disturbance arising from earth currents which generally change sign so slowly that they will scarcely ever interfere with the distinctness of the impulses. For the better working of long lines a test circuit can be constructed (in the office) of resistance coils and induction plates so as to have a similar speed to that of the cable, and by attaching this to the sending key (or apparatus) the operator can see what his currents are doing at the distant end, and if any of his apparatus, or his signalling, or writing be defective he will discover it on this test circuit. To render such a test circuit less costly the induction plates are reduced say ten or more times, the resistance being increased in like ratio so as to get the same speed, large induction plates being costly. When magnetic relays are used I make the contact by means of a very light spring with limited play, the contact piece on such spring being made to project through the spring to prevent the spring from causing the relay to vibrate on the contact pieces; I also use a similar spring at the back of the relay whether it be used for another local circuit or not, as these springs by preventing sticking, and by counteracting the magnetic attraction of the bar, to a certain extent greatly increase the sensibility and certainty of the relay. I sometimes place my galvanometer needles and relay bars in a fluid such as spirits of wine to prevent the needle from oscillating and to give a deadness to their motion.

Several other modes of applying the principle could be devised.

SPECIFICATION in pursuance of the conditions of the Letters Patent filed by the said Cromwell Fleetwood Varley, in the Great Seal Patent Office on the 25th June 1863.

TO ALL TO WHOM THESE PRESENTS SHALL COME, I, Cromwell Fleetwood Varley, of Fortess Terrace, in the County of Middlesex, Electrician, send greeting.

WHEREAS Her most Excellent Majesty Queen Victoria, by Her Letters Patent, bearing date the Twenty-sixth day of December, in the year of our Lord One thousand eight hundred and sixty-two, in the twenty-sixth year of Her reign, did, for Herself, Her heirs and successors, give and grant unto me, the said Cromwell Fleetwood Varley, Her special licence that I, the said Cromwell Fleetwood Varley, my executors, administrators, and assigns, or such others as I, the said Cromwell Fleetwood Varley, my executors, administrators, and assigns, should at any time agree with, and no others, from time to time and at all times thereafter during the term therein expressed, should and lawfully might make, use, exercise, and vend, within the United Kingdom of Great Britain and Ireland, the Channel Islands, and Isle of Man, an Invention for "Improvements in Electric Telegraphs," upon the condition (amongst others) that I, the said Cromwell Fleetwood Varley, my executors or administrators, by an instrument in writing under my, or their, or one of their hands and seals, should particularly describe and ascertain the nature of the said Invention, and in what manner the same was to be performed, and cause the same to be filed in the Great Seal Patent Office within six calendar months next and immediately after the date of the said Letters Patent.

NOW KNOW YE, that I, the said Cromwell Fleetwood Varley, do hereby declare the nature of my said Invention, and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

The object of the said Invention is to obtain a high speed of transmission through long circuits.

The first part of my Invention consists in employing for electro-telegraphy the increment and decreement of electric currents instead of, as has heretofore been the case, the flow of the current itself. I carry this part of my Invention into effect in various modes.

Another part of my Invention consists in the employment of what I term a test circuit formed by induction plates and resistance coils, so adjusted to

each other as to produce an artificial line possessing the same amount of retardation as the cable itself.

Another part of my Invention consists of forming a contact piece of metal in the delicate spring contacts of telegraph instruments as herein-after described.

First mode of carrying out the first part of my Invention:—At the receiving end of the cable is attached a series of induction plates between the earth and the cable connecting the "odd" plates to the one, and the "even" plates to the other. By the term "induction plates" is meant a series of plates of metal insulated from each other, the odd plates being connected together in one series and the even or intermediate plates in a second series. A relay or telegraphic instrument is inserted either between the cable and the induction plates or between the induction plates and the earth. A resistance coil (best if wound on a large iron core) is also inserted between the cable and the earth without these resistance coils the speed of transmission would not be increased. Let it be assumed that a galvanometer relay is the instrument used, on applying a current at the sending end the electric impulse will gradually show itself at the receiving end dividing part into the induction plates and part through the resistance coils to the earth. As soon as the current assumes its maximum force and the induction plates are fully charged the current through the telegraphic instrument ceases although the current continues to flow through the cable. On reversing the current at the sending end the strength of the current at the receiving end decreases preparatory to changing its sign or direction, the moment however that its strength begins to decrease, and long before it changes sign the induction plates by discharging themselves produce a reversal of current in the telegraph instrument. And variation in the strength of the current at the receiving end of the cable in the direction of positive towards negative, or of negative to more negative, causes currents to flow through the telegraph instrument in one direction, while any variation of the current from negative towards less negative or positive, causes currents through the telegraph instrument in the opposite direction. A variation of the strength of the cable current is thus made to produce a reversal of current in the relay or telegraph instrument.

Fig. 1 will explain generally how the various parts are connected. Fluid induction plates (described in my Patent, No. 206, 1860) in consequence of their great capacity may in some cases be used with advantage, but as there is always more or less conduction through them it is necessary to counteract the effect of it in some cases. This can be done by winding the instrument

coils with two wires (vide. Fig. 2) and causing a part of the current from the induction plates to pass round the instrument coils in an opposite direction to the first current; when this is over done or over corrected (whatever kind of induction plates be used), a relay can be constructed which records only when the increment of tension is increasing in rate in one direction and vice versâ; this is shewn in Fig. 2. A second resistance coil is inserted between *a* and *b*, and by varying its resistance the proper amount of compensation is obtained.

Second mode.—By substituting for the telegraph instrument in Fig. 1 an electroscope and connecting its two poles by a resistance coil. The electroscope should have several bars for repulsion or a broad plate of metal instead of one thin wire, and these must be made short to get rapidity of action. This electroscope may be used to close a local circuit like a galvanometer relay. Any variation in the intensity of current through the cable causes a difference of tension between the cable and the induction plates, and this shews itself on the electrometer producing a signal or result similar to those obtained by the arrangement shown in Fig. 1. By inserting one of my multipliers rotating rapidly almost any amount of power may be obtained (vide Figure 20 in my Patent No. 206, 1860).

Third mode.—By means of a large electro-magnet requiring an appreciable time to magnetise. The electro-magnet (or induction coil) of large dimensions is wrapped with two wires, one acting as a primary and connected between the cable and the earth, the other acting as a secondary is attached to the telegraph instrument when the current from the cable passes through the one coil to earth, the iron is magnetised, and so long as the iron is being magnetised so long is there a magneto-electric or secondary current circulating in the other wire in the opposite direction; as soon as the current ceases to increase in strength the magnetism of the iron ceases to augment, and there is no current in the second wire; the moment however the current begins to decrease in strength the magnetism of the iron decreases, and a magneto-electric current is produced in the secondary wire in the opposite direction to the current which was produced whilst the iron was increasing in magnetism, thus variations of force of the current through the cable whether they change sign or not produce distinct signals or reversals of current in the secondary wire. If this secondary wire be connected to a relay or one of Thomson's reflecting galvanometers, the signals are recorded or may be read off distinctly although the cable currents do not pass the zero point; Fig. 3 will explain this.

My fourth mode consists in winding the instrument coils with two wires of different lengths and of different number of convolutions. For ease of explanation let it be assumed that the first wire has but half the resistance and half the number of convolutions of the second wire, let there be an electro-magnet or induction coil with a resistance equal to that of the second wire, and that the first and second wires are joined together and to the resistance coil. Any current passing through the first wire and arriving at the junction of the resistance coil and the second wire splits. As these two channels offer the same resistance the current equally divides, but as the half that traverses the relay in the opposite direction to the first current passes twice as often round it the magnetic effect of the first wire is exactly neutralized, consequently no action would be produced in the relay, were it not that the iron of the induction coil during the period of its magnetization offers an obstruction to the passage of the current and during this interval of time more than one half of the current flows round the second wire of the relay, and produces a signal as before. The induction plates might be applied in place of the electro-magnet.

Fifth mode.—The currents are made to go round two galvanometers of different dimensions, the needles of which have different inertia, but so connected as to move in the same direction and to the same angle with a given current. The larger and slower of the two is wound with more convolutions, so as to give a greater angular deflection with a given amount of current, but a portion of this current is shunted off by resistance coils, not shown in the Figure, so as to give precisely the same deflection as the smaller one. These galvanometers are formed into a relay thus:—Their two axles are placed end to end in the same vertical line, but not in metallic connection. The one axle carries an insulated fork, one arm of which is insulated, on the other there is a small delicate spring contact (vide the fork in Fig. 4, also see Figures 5 and 6.) When the needles are moved in one direction the piece *b* presses against the spring contact *a*, Fig. 4, which consists of a delicate spring and a small bead of platinum or gold to make the contact, the play of this spring being limited by the hook *c*. When the motion is in the opposite direction the local circuit is opened or from the fork, Figures 5 and 6, the wire *a* hangs down in the semicircular trough. The other axle carries an arm which vibrates between the fork and hangs down by the side of the other wire in the trough. (The wire or arm *b* is insulated from the fork *a* by glass or other suitable material.) In this trough there is a wire which runs along the bottom or on one side of it. The trough is filled with water or other

suitable solution. The wire at the bottom of the trough is connected to one pole of the battery, the other pole being connected to one of the galvanometer axles; from the middle of the battery the wire passes round the "second relay," Fig. 5, through the second galvanometer axle. When the cable current is varying in one direction the smaller needle, owing to its more rapid motion, brings the two arms in the fluid closely together; but when the current varies in the opposite direction the more rapid action of the smaller magnet increases the distance between the two arms in the water. When the distance between these arms is properly adjusted it will be found that when the arms are at a distance from one another a current in one direction flows through the "second relay;" when the arms are close together a current in the opposite direction flows through the "second relay," owing to the variation of resistance caused by the distance these arms are separated from each other in the water. By inserting resistance coils between the battery and the wire at the bottom of the trough, and between the axle and its other pole, these currents can be so adjusted that a variation of distance of less than one-tenth of an inch shall produce sufficiently powerful reversals of current in the second relay. Induction plates, not shown in the Figure, may with advantage be connected between the earth and the junction of these galvanometers. During my experiments I have found that it is not necessary in all cases to use the second galvanometer coil and needle, the axle alone being retained with its fork. The fork and its axis may also be dispensed with in the following way, when the projecting arm touches nothing but water. The galvanometer needle carries an arm dipping into the water, as shown in Figure 7; the battery is connected by a plate to one end only of the trough instead of all along the bottom or side thereof. The other pole of the battery is connected to the primary wire of an induction coil through it to the axle of the galvanometer, which has an arm *b* dipping down into the water. A closed circuit is thus formed, the current passing from the battery through the primary coil of the induction bobbin, through the plate *q* and the water to the galvanometer arm *b*, and back to the battery. The secondary wire of this induction coil is connected with a polarized relay or any other suitable telegraph instrument. When the needle is deflected in the one direction the distance between the moveable arm in the water and the wire at the end of the trough is decreased, while when it moves in the opposite direction it is increased, causing a great variation in the resistance of the circuit. Thus while the needle is moving in the one direction through the water the current through the primary is increasing in strength, and when moving in the opposite direction the current

through the primary decreases in strength. While the magnetism of the bobbin is increasing there is a comparatively feeble current in the one direction through the secondary wire, and while decreasing there is a current in the opposite direction. Thus, then, while the needle is being deflected in the one direction the relay is closed, and the moment it begins to move in the opposite direction the relay is opened. In this way a feeble electric current is made to act upon an ordinary relay, which in turn acts upon any recording instrument to which it may be applied. Owing to the great resistance which water offers to the passage of electric currents a small amount of motion produces a very considerable variation in the strength of the current passing through the primary wire, the galvanometer needle should be light and should be made to oscillate rapidly. This may be effected by using a large permanent magnet outside the coils, or two opposing currents of air issuing from pipes against the bars *a* or *b*, or the water in the trough *l* may be made to flow in opposite directions, as indicated by the dotted portion of Figure 6, and out at the centre. The water cistern is not shown. When the relay is constructed to make contact between metal stops, as in all electric relays hitherto used, the contact piece may be made to strike against a wheel or between two wheels rotating, which wheels may be covered with a porous material, such as cloth slightly moistened with a suitable conducting fluid, such as chloride of zinc or calcium. By these arrangements the "sticking" of the relay, when very feeble currents are used, may be wholly or partially prevented. When an ordinary relay is used the following method is adopted of securing good electric contact, and if it be a polarized relay its sensibility is greatly increased at the same time.

Fig. 8 shows the iron bar of a polarized relay, the springs *s*, *s*, are provided with the little beads of platinium *p* which remove the tendency to vibration experienced when a flat spring against a flat surface is used. These springs, by overcoming part of the magnetic attraction of the permanent magnets N, S, augment the sensibility of the relay.

Fig. 9 shows another mode of effecting the same purpose with double contacts c and c^1, one being a spring, the other a dead contact. Either of these methods, by maintaining a good electric contact during the vibration on the stop, greatly augments the speed of working. The oscillation and vibration of the moveable parts of telegraphic and electric apparatus may generally be deadened by placing those parts partly or wholly in a fluid. The various plans described may be combined partially or wholly together, according to the requirements of the case. As earth currents change their sign very slowly,

compared with signalling currents, it will be seen at a glance that although the current flowing through the cable may be strong, yet as its increment of tension is slow, little or no perceptible action is produced upon my signalling apparatus, and thus high speed and immunity from the effects of earth currents are simultaneously secured.

The methods that I prefer at the signalling end for working long submarine lines are shown in Figures 10, 11, 12, and 13, induction plates are inserted between the cable and the earth. When the battery is reversed, as shown by the dotted lines, the tension of the induction plate is added to that of the battery to change rapidly and sharply the electrical condition of the cable. In Fig. 11 resistance coils are shown connecting the two armatures of the induction plates to cause a feeble current to flow after the first sharp sudden current. In some cases, however, it may be advisable to connect the cable to the earth through an induction coil consisting of a large bundle of iron wire surrounded by a long length of fine wire, as in Fig. 12, the action of which is as follows:—On reversing the battery connections the induction plates and battery combined send a short impulse into the cable, which divides one portion into the cable, the other through the induction coil to the earth. At the first moment the iron of the induction coil offers resistance to the passage of the current, consequently during the first instant of time nearly the whole force of the current is applied to the cable. As the iron becomes magnatized to its maximum this opposition ceases, but the plates have become charged in the opposite direction, and there is no longer any current passing from them into the cable to maintain the magnetization of the iron, the demagnetization of which induces a current in the coil and discharges the cable. In this way each impulse is followed by a short impulse in the opposite direction. By connecting the two "armatures" of the induction plates with a set of resistance coils, this reversal of the current is followed by a weak second reversal in the same direction as the original current, vide, Figure 13, in this Figure the induction coil is represented as wound with two wires, and connected as shown.

In working long submarine cables one of the difficulties to be contended with is the impossibility of knowing what is transpiring at the distant end. To obviate this difficulty I propose constructing what I call a "test circuit," consisting of induction plates and resistance coils, so adjusted to each other as to produce an artificial line possessing the same amount of retardation as the cable itself. This "test circuit" is to be attached to the sending end of the cable, and in this way, if any portion of the sender's apparatus get out of order, or his currents be not properly adjusted, the "test circuit" will show

him what his correspondent at the distant end is probably receiving, and thus he can know himself that, as far as his sending apparatus is concerned, whether all is right or wrong, and if wrong apply the necessary remedy, or decrease his speed of transmission to such a pitch as shall give distinct and intelligible signals, vide, Fig. 14. To save expense, the resistance of this test circuit may be increased, say, 10-fold, when the induction plates are reduced in size in like proportion, the signal currents will of course be but one-tenth the strength of those received through the cable, but yet sufficient for test purposes. By this means twelve square feet of my induction plates about equal ten miles of cable.

Having found difficulty in constructing large induction plates with certainty, I have been led to try, amongst many other insulators, paraffine, and I find that paper saturated with it forms an excellent insulator for this purpose. And also that when the insulators for aerial lines are coated with it their insulating power is increased. The liquid as well as the solid paraffine effect the latter result. When it is desirable to keep the line always negative and yet work with reversals, this may be done by applying batteries at each end of the line, between it and the earth, their positive poles being to earth.

Description of the Diagrams.

It would be almost impossible to draw the apparatus as they appear, and convey at the same time a proper idea of their construction. The parts therefore essential to this Invention only are shown, and the rest, which is easily understood by all telegraph engineers competent to make and work these apparatus, is omitted. Again, no particular form or shape of the various parts of this Invention is claimed.

Figure 1 a telegraph instrument, is connected in circuit between the induction plates and the receiving end of the cable, but it might be placed with similar results between the induction plates and the earth.

Figure 2 shows how the second wire is wrapped on the instrument to compensate for any leakage that may exist between the induction plates. The resistance coils between *a* and *b* are to cause the necessary amount of compensation current to flow round the outer coils of the telegraph instrument in the opposite direction to that which flows through the inner coil after the induction plates are fully charged, in consequence of any leakage that may exist in the plates. When the resistance of these coils is infinite the compensation current is at its maximum. When the resistance is "nil" the compensation is entirely cut off, and the instrument is then precisely similar in action to that in Figure 1.

Figure 3 represents an induction coil. *p* is the primary coil wrapped upon the iron core *i*; *s* is the secondary wire connected with the telegraph instrument. The core of the induction coil consists of a bundle of iron wires, 4 times the length of the bobbin on which the primary and secondary are wound, and these iron wires are spread out and bent back over the coil so as entirely to encase it, and by which the secondary current is greatly augmented in force; vide my Patent, No. 3059, 1856, Figure 14.

Figure 4 represents a fork placed on the axle *d*, vide Figures 5 and 5A. When the local circuit is closed by the metallic contact of *a* and *b*, one side of the fork is insulated, as shown at *e*, the other fork has a hook at *c* to retain the spring *f* in position. On this spring there is a little ball of platinum, formed by putting a piece of platinum wire through the gold spring *f*, and riveting it in a steel mould, similar to a small bullet mould. This arrangement, by preventing the spring from touching the arm *c*, excepting when the ball of platinum strikes the arm *c*, prevent the vibrating contact which would be produced by the irregularities of the spring which it is impossible to make absolutely flat.

Figures 5 and 5A represent two galvanometer coils. The lower axle *d* carries a short needle N^1, S^1; the upper needle N, S, is mounted on an axle *g*. These axles are mounted in the frames *j* and *k*, which are fixed on the board *w*, and insulated from each other. On *d* is mounted the fork *a*, between which the bar *b* plays; *b* is insulated from *a*, and both of them dip down into the trough *b*.

In Figure 6 there is a wire at the bottom of the trough *l*. The two adjacent sides of the wires *a* and *b* in the trough are uninsulated. The other portions are covered with an insulating varnish. The various parts are connected, as shown in Figure 6. Suppose for a moment the second relay disconnected, there is a positive current flowing from the positive end of the battery through the wire at the bottom of the trough to *a*, from *a* through the resistance coils to the battery. From the centre of the battery there is another circuit through the second relay to the axle *g* and the pin or wire *b*. If the resistance coils be cut out of circuit it will be evident that when the resistance between *a* and *b* through the water is less than between *b* and the wire at the bottom of the trough, there will be a positive current flowing from *a* through *b* through the relay to the battery. When, however, by moving the wire *b* to the other side of the fork, the resistance between *a* and *b*, owing to the increase of distance, is greater than the resistance from *b* to the wire at the bottom of the trough, a positive current will flow through the relay from the battery

through *b* to the wire *l*; this, when *a* and *b* are near together, the positive current flows in one direction through the second relay, when *a* and *b* are at a distance the positive current flows in the opposite direction. Let it now be assumed that the two needles have been deflected to any position by a current through the cable of a given strength, and that this current be reduced in power, the needles will fall back. The small one, owing to its less inertia, moves quicker than the large one, and consequently will increase the distance between the bars *a* and *b* in the water. If the current through the cable augment in power, *a* and *b* will approach in consequence of the more rapid motion of the small needle, and thus when the needle is moving in the one direction through the trough *l*, there is a current in one direction through the "second relay," when moving in the opposite direction there is a current through the "second relay" in the opposite direction, vide Fig. 6. In Figure 6, however, the upper needle and its coil are removed, they having been found in practice not always to be necessary. The dotted taps *t* shown in Figure 5 are connected with any convenient supply of water, and by regulating the flow of the current through the trough out at t^1, the bars *a* and *b* are maintained opposite t^1 when no electrical current is acting upon their needles.

Figure 7, N, S, is a needle mounted on a coil, similar to that in Figure 5 A carrying the wire *b*, dipping into the trough *l*. A current flows continuously from the battery through *b*, through the water in the trough to the plate *q*, thence through the primary wire of the induction coil to the battery. When the needle is deflected the wire *b* is carried nearer to or further from *q*, increasing or decreasing the resistance in the circuit accordingly. This gives rise to a current in the induction coil which works the telegraph instrument, as previously described. The trough in this arrangement is made to decrease in width from *q* to *r*, to increase the resistance as the wire moves from *q* in a greater ratio than its motion, otherwise when the needle is near *q* a given deflection would produce stronger secondary currents than the same deflection would do near *r*.

Figure 8 represents one of my improved relays, vide Patent No. 3059 (1856), Fig. 6 and 7, to which spring contacts *s*, *s*, are applied, briefly described in Figure 4. When the relay bar *i* is deflected from one side to the other it vibrates upon the contact screw *c* like a hammer on an anvil, and a small fraction of a second of time is lost thereby. In my galvanometer relays (Patent No. 371, 1854) I used a spring to keep up the contact during this vibration, but the impossibility of getting a flat delicate spring to strike flat upon its stop piece causes the force of the spring to augment very greatly

when it touches in more than one place. The little globes of platinum *p*, *p*, do away entirely with this difficulty, because the spring does not itself touch the bar *i* excepting by its globe of platinum *p*; this being made in the form of a globe makes it strike fair each time without any tendency to twist.

Figure 9 represents a part of a similar relay, in which the same object is effected with one spring s^1 instead of two. The two screws *c* and c^1 are electrically connected together as shown in the Figure. When the iron bar *i* is deflected towards *c* and c^1 the spring *s* and its platinum point *p* first come in contact with *c*, the bar, however, is deflected on against c^1, the spring *s* yielding. The vibrations take place upon the point of c^1, but during this interval of time the electric contact is maintained by the spring *s*. These springs make the connection of the relay much more certain, and enable a considerable higher speed to be obtained. The strength of the springs *s* should be just such as to almost overcome the magnetic attraction of the permanent magnets S, N, and so enable a very feeble current indeed to move the bar *i* from side to side. These springs also get rid of the difficulty known as sticking, caused chiefly by the spark which takes place on making contact, and also from greasy matter on the points of contact.

Figures 10, 11, 12, and 13 represent the disposition of apparatus that may be used at the sending end to compensate the current at the receiving end, and so get a higher rate of working; vide my Patent, No. 206 (1860), p. 9. The dotted lines at the battery indicate that the poles are to be changed by any suitable reversing key, well understood by telegraph engineers. In Figure 10 induction plates alone are inserted between the battery and the cable. In Figure 11 the resistance coils are shown connecting the two sides of the induction plates. The object of these coils is to cause a weak continuous current to flow through so long as a battery is connected to it. In Figure 12 the induction coil or primary coil is placed between the cable and the earth, the effect of which is, as previously described, to cause a reversal of current after each impulse. Figure 13 represents an induction coil with primary and secondary wire. In it are represented by the dotted lines resistance coils, which if added to this arrangement, or to that shown in Figure 12, produces a very high compensation, first pointed out by Professor Thomson, of Glasgow, viz., if the first current be positive it is followed by a negative and afterwards by a weak positive through the resistance coils. The key at the sending end may be constructed so as to put the cable to earth for a short time when reversing the battery connection in Figure 10 or 11, so as to discharge the cable to earth before the battery is reversed. This will be understood by all

acquainted with telegraphy, and need not therefore be described, as the importance of discharging cables has been sufficiently pointed out in my first Patent, 1854, No. 371.

In the Specification and in the description of the Diagrams the system of telegraphing is assumed to be that invented by myself in 1854, Patent No. 371, in which the signals are produced by a positive current, and the intervals by a negative current; but other modes of signalling might have been adopted.

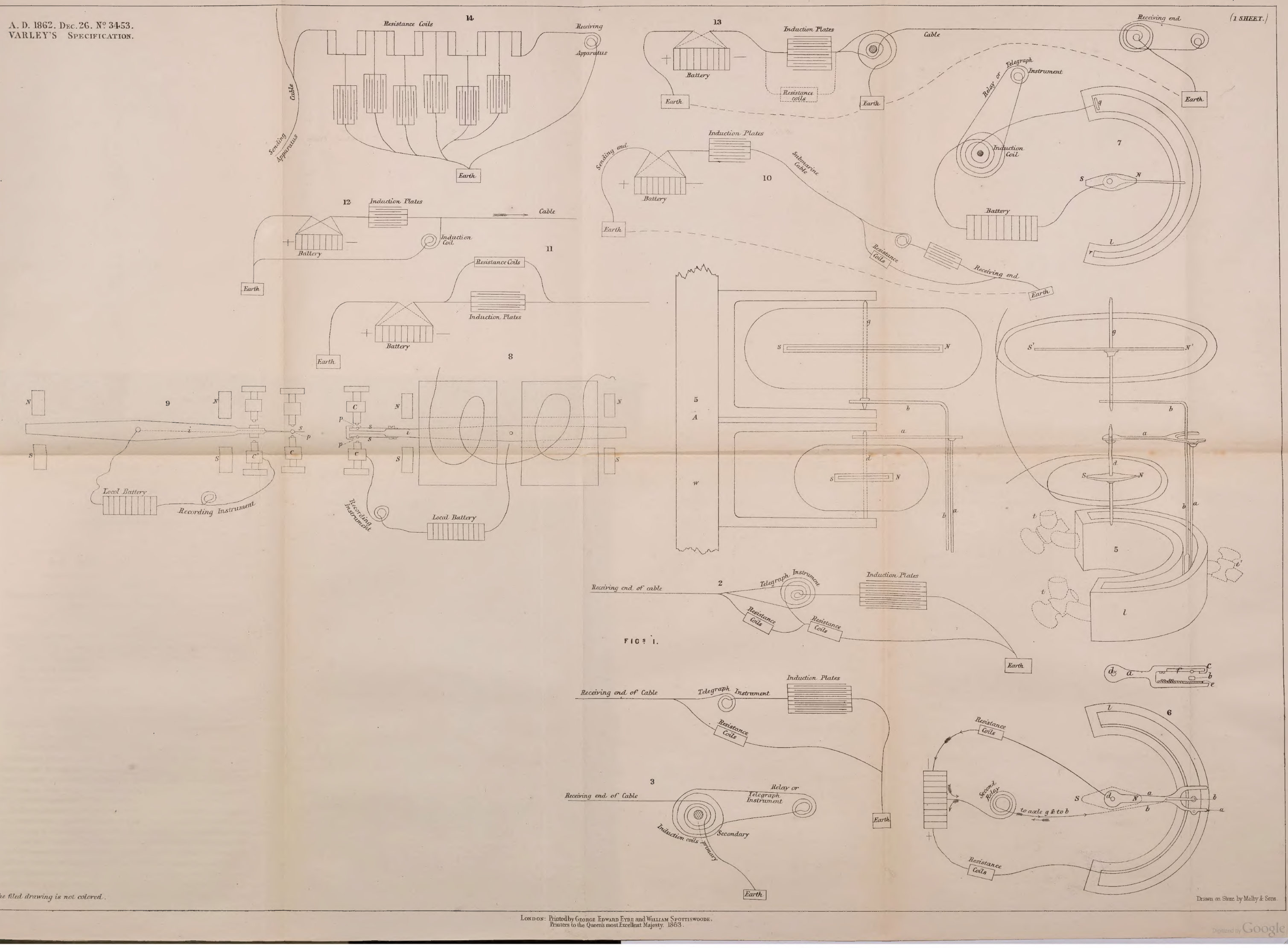
In witness whereof, I, the said Cromwell Fleetwood Varley, have hereunto set my hand and seal, this Twenty-fifth day of June, in the year of our Lord One thousand eight hundred and sixty-three.

CROMWELL FLEETWOOD VARLEY. (L.S.)

LONDON:
Printed by George Edward Eyre and William Spottiswoode,
Printers to the Queen's most Excellent Majesty. 1863.

A. D. 1862. Dec. 26. Nº 3453.
VARLEY'S SPECIFICATION.

(1 SHEET.)



The filed drawing is not colored.

Drawn on Stone by Malby & Sons.

LONDON: Printed by GEORGE EDWARD EYRE and WILLIAM SPOTTISWOODE,
Printers to the Queen's most Excellent Majesty. 1863.